PHOTOSYNTHESIS IN PLANTS

- Green plants – Autotrophs.
- Photosynthesis – Physico-chemical process → for synthesis of organic comp.

* Ultimately, all living organism $\xrightarrow{\text{depend on}}$ sunlight (for energy)

* Use of energy from sunlight by plants $\xrightarrow{\text{for doing}}$ photosynthesis → Basis of life on earth.

* $\boxed{\text{Photosynthesis}}$ imp for 2 reasons
→ Primary source of all food on earth.
→ Release of O_2 into atmosphere by green plants.

○ For starch presence – variegated leaves are taken. or leaf covered by black paper.

○ For testing CO_2 imp – Part of leaf → enclosed in a test tube $\xrightarrow{\text{containing}}$ KOH soaked cotton (which absorbs CO_2) while other leaf exposed to air → set up placed in light → on testing for presence of starch
- Part exposed to air → +ve
- Part inside test tube → –ve

] this showed → presence of CO_2 is important

PAR → 400 – 700 nm.

EARLY EXPERIMENTS

JOSEPH PRIESTLEY (1733 – 1804)

In ~~1990~~ 1770, he performed a series of experiments
↓ revealed
Essential role of O_2 (air) in the growth of green plants.

Priestly $\xrightarrow{\text{discovered}}$ O_2 in 1774.
→ he observed → candle burning in a jar (closed)
↓
soon gets extinguished

If mouse is kept → soon would suffocate

He concluded → (1) Burning candle (2) animal both somehow damage the air.

If a MINT plants → placed in jar →  then mouse & candle remained → alive.

He hypothesized → Plants restore to air whatever burning candle & animals remove.

JAN IGENHOUZ (1730 - 1799)

Used a similar set-up as Joseph Priestley → by placing in light & dark once - once.
Showed — Sunlight essential for plant process.
Used — Aquatic plant (HYDRILLA) in → bright sunlight → small bubbles are formed around green plants → O_2

In dark - no bubbles.

JULIUS VON SACHS (1854 me)

Provided evidence — Glucose is prod. when plants grow.
↓ stored as
Starch.

He showed — Green subs. in plants is located in special subst.
↓ CHLRORHYLL ↓ CHLOROPLAST

T.W ENGELMANN (1843 - 1909) → described Ist action spectrum.

* Used - PRISM → to split light into spectral component.
* Illuminated — A Green Alga — CLADOPHORA.
  placed in a suspension of
  Azotobactor ← [Aerobic Bacteria] —used to→ detect sites of O_2 evolution.
* He observed — Bact mainly accumulated in the → Red reg. / → Blue reg. → of split spectrum.
* Action spectrum resembled → Absorption spectra of → chl·a / → chl·b.

By middle of 19 th century,

⇒ Empirical eqn. was given ⟶

$CO_2 + H_2O \xrightarrow{Light} [CH_2O] + O_2$

[CH₂O] ⟶ represents a carbohydrate [eg – Glucose] (6-C sugar)

• MILESTONE $\xrightarrow[By]{made}$ (CORNELIUS VAN NIEL (1897 - 1985))

⟶ *Microbiologist*

* Based on studies of ⟶ purple bact. (sulphur) / ⟶ Green bact. (sulphur)] $\xrightarrow[that]{demonstrated}$ photosynthesis ↓ is Light dependent reaction.

Carbohydrates ⟵ CO₂ $\xleftarrow{reduces}$ Hydrogen $\xleftarrow[which]{in}$

↓ from

suitable oxidisable comp.

$$2H_2A + CO_2 \xrightarrow{light} 2A + CH_2O + H_2O$$

• In green plants ⟶ H_2O ⟶ Hydrogen donor

$\xrightarrow[to]{oxidized}$ O_2

• Some organisms ⟶ DONT RELEASE O_2

∘ In ⟶ purple sulphur bact / ⟶ Green sulphur bact.] ⟶ H_2S ⟶ Hydrogen donor.

∘ Oxidation product is ⟶ sulphur / ⟶ sulphate] ⟶ *depending on ORGANISM* not O_2.

(He inferred ⟶ O_2 $\xrightarrow[from]{comes}$ H_2O) ⟶ proved by later RADIOISOTOPIC TECHNIQUES. (Ruben Kamen et al.)

$$6CO_2 + 12H_2O \xrightarrow{light} \underbrace{C_6H_{12}O_6}_{glucose} + 6H_2O + 6O_2$$

not radioactive its radioisotopic

O^{18} ⟶ stable non radioactive heavy.

Multistep Process – Photosynthesis.

Where does Photosynthesis occur?

- Photosynthesis $\xrightarrow{\text{occurs in}}$ green leaves, some other green parts too.
- Mesophylls cells $\xrightarrow{\text{in}}$ leaves has greater no. of chloroplast, align along the walls of Mesophyll cells ~~chloroplasts~~ $\xleftarrow{}$ such that they get optimum quantity of incident light.

* Within chloroplast $\xrightarrow{\text{there is}}$ membranous system
- grana
- stroma lamellae
- matrix stroma.

(★ Imp line) → There is clear cut division of labour within chloroplast

* Membrane System $\xrightarrow{\text{is responsible for}}$ trapping light-energy, $\xrightarrow{\text{synthesis for}}$ ATP & NADPH. → LIGHT RKN (Photochemical rkn)

* Stroma $\xrightarrow{\text{here occurs}}$ enzymatic rkn $\xrightarrow{\text{for synthesis of}}$ sugars $\xrightarrow{\text{forms}}$ starch → DARK RKNS (Carbon rkns) → not directly light driven but depended on products of light-direction.

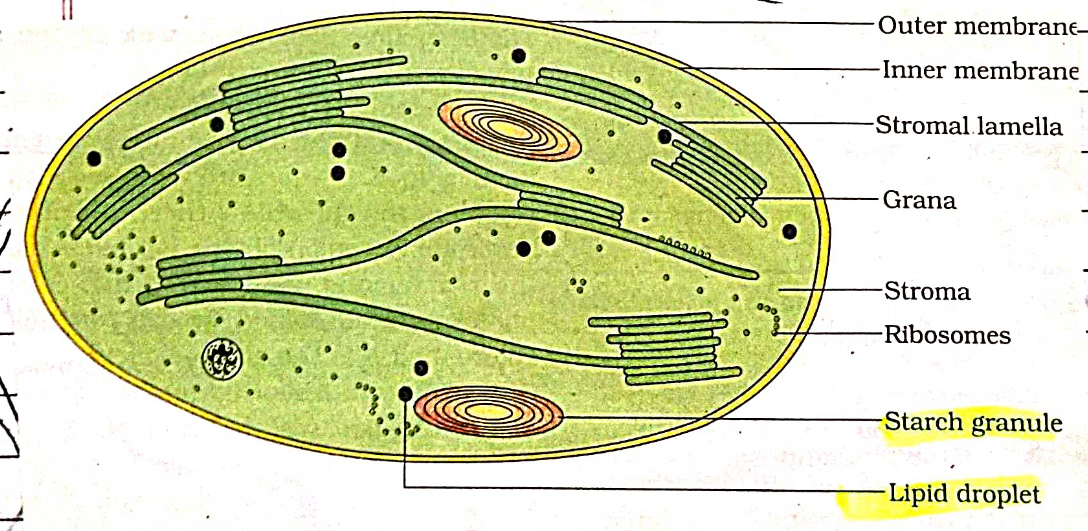


Figure 13.2 Diagrammatic representation of an electron micrograph of a section of chloroplast

How Many types Of Pigments are involved in Photosynthesis?

Leaf pigments $\xrightarrow{\text{are seperated by}}$ Paper chromatography

Chlorophyll a	Chl. b	Xanthophyll	Carotenoids
↓	↓	↓	↓
Bright or blue green	Yellow green	Yellow	Yellow / yellow orange

↳ in chromatogram

accessory pigments (Chl. b, Xanthophyll, Carotenoids)

Pigments $\xrightarrow{\text{are}}$ substance $\xrightarrow[\text{ability to}]{\text{that have}}$ to absorb light at specific wavelengths

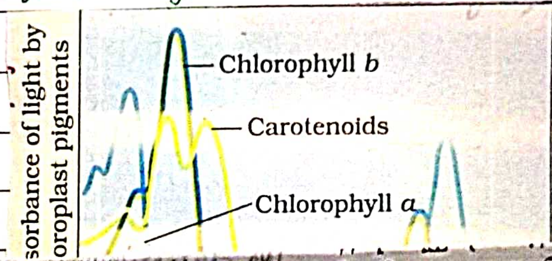
$\boxed{\text{Chlorophyll a}}$ ⟶ chief pigment associated with photosynthesis

- Max^m photosynthesis $\xrightarrow[\text{in}]{\text{occurs}}$ Red, Blue region
- Some photosynthesis $\xrightarrow[\text{in}]{\text{occurs}}$ other regions too, other λ of visible spectrum.

$\boxed{\text{Accessory pigments}}$ $\xrightarrow{\text{absorb}}$ light & transfers energy $\xrightarrow{\text{to}}$ Chl a.
$\xrightarrow{\text{enable}}$ wider range of wavelength of incoming light to be utilised for photosynthesis.
protects Chl a from photo-oxidation

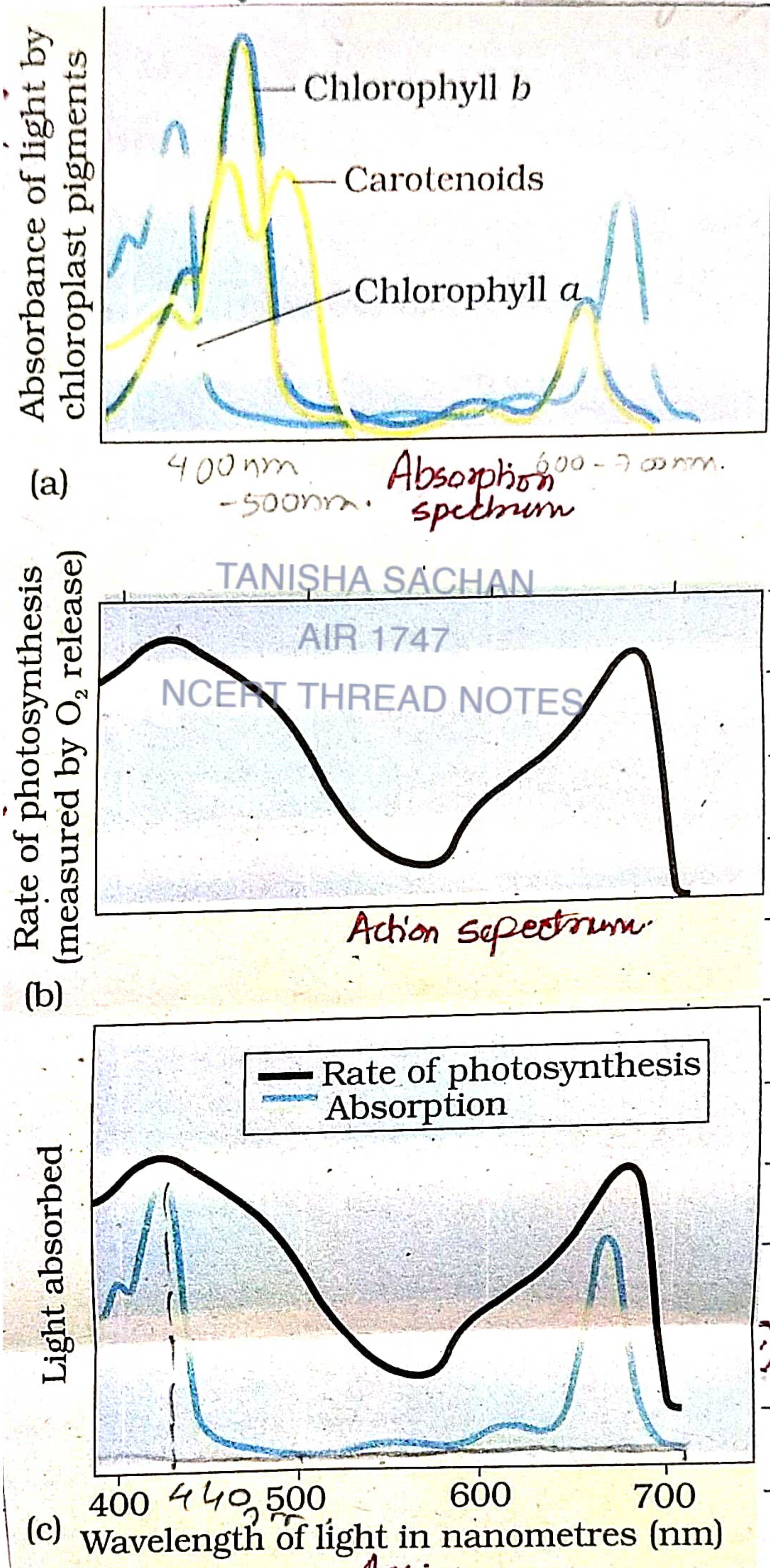
Rate of photosynth. was measured by = O_2 release.

Graph ⟶



WHAT IS LIGHT RXN?

* Light Rxn $\xrightarrow{\text{or}}$ Photochemical phase $\xrightarrow{\text{includes}}$
  - → light absorption
  - → Water splitting
  - → O_2 release
  - → Form. of high energy chemical intermediates → ATP, NADPH
* Several protein complexes $\xrightarrow[\text{in}]{\text{are involved}}$ process
* Pigments are organised into 2 → discrete → photochemical ⟶ LHC (light harvesting complex) → within → PS I, PS-II — named in sequence of their discovery (~~function~~)
* LHC $\xrightarrow{\text{made up of}}$ 100's of pigments bound to protein molecule
* Each Photosystem $\xrightarrow{\text{has}}$ all the pigments (except 1 mol. of Chl. a) forming → $\boxed{\text{antennae}}$ light harvesting system



13.3a Graph showing the absorption spectrum of chlorophyll *a*, *b* and the carotenoids

13.3b Graph showing action spectrum of photosynthesis

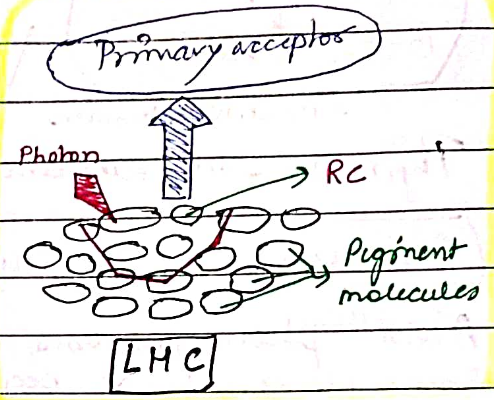
13.3c Graph showing action spectrum of photosynthesis superimposed on absorption spectrum of chlorophyll *a*

* These pigments help to make → photosynthesis more efficient by absorbing → different ' λ ' of light

* Single chl-a forms → (Reaction centre) → different in both PS

PS-I
↓
RC chl-a
↓ has
peak at 700 nm
(P700)

PS-II
↓
RC chl-a
↓ has
peak at 680nm
(P680)



THE ELECTRON TRANSPORT

PS-II → the reaction centre of chl-a absorbs → 680 nm. (of RED light) → causing → e^- to become excited

jump into an → orbit → farther from → atomic nucleus → these → e^- are picked up by → an electron acceptor

which passes them to → ETS (consisting - cytochromes) → * This movement of e^- is downhill. in terms of Oxid-Reduct. / Redox potential scale

e^- are not used up, but passed on to pigments of ← PS-I

Simultaneously, e^- in PS I are excited when they recieve → 700 nm: RED LIGHT

e^- transported to

Another acceptor molecule that has → greater redox potential

these e^- are then → moved downhill again → this time to a mol → $NADP^+$ changes to → $NADPH + H^+$ (energy rich)

Living org have → capability of extracting energy → from Oxidisable substance & store this in form of BOND ENERGY

* Special subs like → ATP, carry this energy in their → chemical bonds

Photo-phosphorylation is → Synthesis of ATP from → ADP, Pinorg. in presence of LIGHT

The process through which in cells ATP synthesis occurs → Mitochondria / Chloroplast → PHOSPHORYLATION

Z scheme

Z scheme $\xrightarrow[\text{o/ts}]{\text{due to}}$ characteristic shape

formed when ↓

* all carriers placed in a sequence on redox potential scale.

↓

Whole scheme of transfer of e^-

$\xrightarrow{\text{starting from}}$ PS II $\xrightarrow[\text{to a}]{\text{uphill}}$ acceptor

acceptor $\xrightarrow[\text{ETC to}]{\text{down the}}$ PS I $\xrightarrow[\text{to another acceptor}]{\text{excitation of } e^-}$ acceptor

acceptor $\xrightarrow[\text{down the line}]{\text{finally}}$ $NADP \xrightarrow{} NADPH + H^+$

↑ reducing by e^-

Splitting Of Water

associated with PS-II

How does PS II supply e⁻ continuously → achieved by e⁻ availability due to → e⁻ removed from PS II must be replaced.

Reaction → $2H_2O \longrightarrow 4H^+ + O_2 + 4e^-$

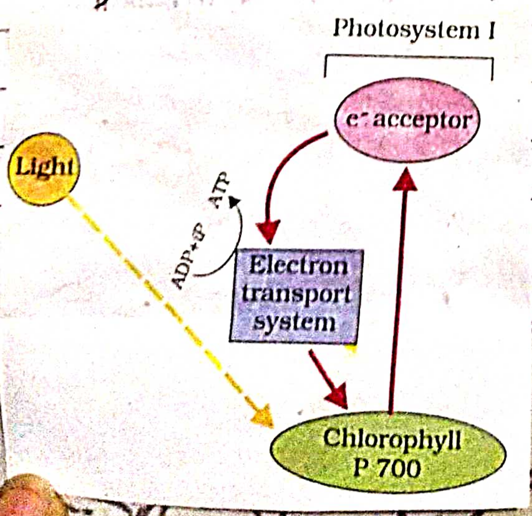
O_2 → one of the net products of photosynthesis, is created here.

(*) e⁻ needed to replace those removed from → PS I are provided by → PS II

* WATER SPLITTING COMPLEX associated with → PS II
  located on → inner side of membrane of thylakoid.

Cyclic Photophosphorylation

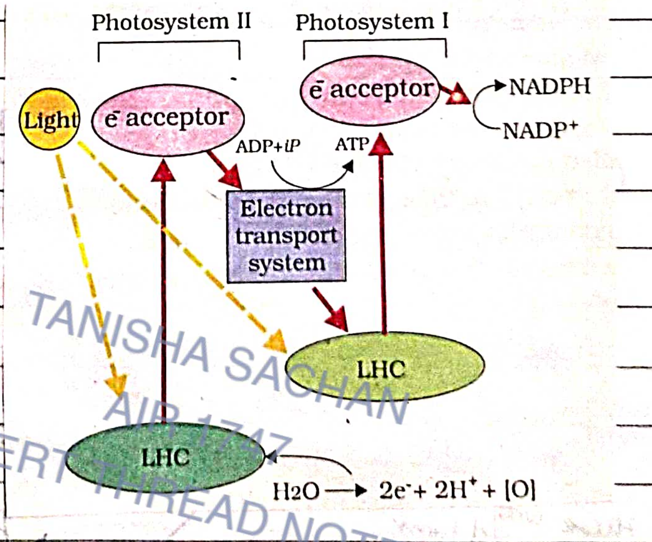
* Only PS I functional.
* e⁻ circulated within photosystem & phosphorylation occurs due to cyclic flow of e⁻.
* Happens in stroma lamellae
  lacks → PS-II, NADP reductase enzyme.
* Occurs when light of λ BEYOND 680 nm available for excitation.
* Excited e⁻ → do not pass on to NADP+ but is recycled back to PS I (through ETS)
* Only ATP synthesis occurs



Non-Cyclic Photophosphorylation

* Both PS I & PS II works
  they work in series
  Ist → PS II
  IInd → PS I
* 2 phosystems are connected by → ETS (as in Z scheme)
* Both produced → ATP, NADPH + H⁺

Z scheme –



Cheimosmotic Hypothesis $\xrightarrow{\text{mechanium to explain}}$ synthesis of ATP in Chlorop...

membrane $\leftarrow$ across proton gradient $\leftarrow$ a development of $\leftarrow$ linked to the

membranes are of $\rightarrow$ Thylakoid

	In Respiration	In photosynthesis
Proton accumul-ation	In intermembrane space of mitochondria	Towards inside of the membrane i.e lumen.

Process that take place which causes $\rightarrow$ activation / transport of $\rightarrow$ e⁻ & determine the cause of proton gradient to develop.

1. Splitting of H_2O (Takes place $\xrightarrow{\text{on}}$ inner side of the membrane)
2. Protons / H^+ that are produced by $\xrightarrow{\text{accumulate within}}$ lumen of Thylakoids
3. As e⁻ moves through photosystems, protons $\xrightarrow{\text{transported}}$ across the membrane.

BECAUSE

4. PRIMARY ACCEPTOR OF e⁻ $\xrightarrow{\text{located towards}}$ outer side of the membrane

transfers its e⁻ to $\rightarrow$ H carrier (not a e⁻ carrier)

5. This molecule removes a H^+ $\xrightarrow{\text{from}}$ stroma $\xrightarrow{\text{while}}$ transporting an e⁻.

When this molecule

6. Passes on its e⁻ $\xrightarrow{\text{to the}}$ e⁻ carrier $\xrightarrow{\text{on}}$ inner side of membrane
7. H^+ is released into the $\rightarrow$ inner side of membrane / LUMEN

* NADP reductase enzyme $\xrightarrow{\text{located on}}$ stroma side of membrane.

* Along with e⁻ $\xrightarrow{\text{that comes from}}$ acceptor of e of PS-I

these are removed from stroma. $\leftarrow$ Protons

NADPH + H^+ $\xleftarrow{\text{reduction}}$ NADP⁺ $\leftarrow$ necessary for

Within chloroplast → H^+ in the stroma (↓↓↓)

Within Lumen → accumulation of H^+ (pH ↓)

this creates → Proton gradient → across → Thylakoid membrane

* Breakdown of this → proton gradient → that leads to → synthesis of ATP

due to movement → of H^+ → across → the membrane → to → stroma

through: TRANSMEMBRANE CHANNEL OF CF_0 of ATP synthase.

ATP Synthase Enzyme

CF_0	CF_1
• Embedded → in → Thylakoid memb. • Transmembrane channel. • Carries out → FACILITATED DIFFUSION of H^+ (across the membrane)	• Protudes on the outer surface of thylakoid membrane. on the side that → faces stroma.

* Breakdown of proton gradient → provides → enough energy → to cause a → conformational change → in the → CF_1 particle → of → ATP Synthase

which makes → enzyme synthesise → several mol. of energy packed ATP.

* CHEMIOSMOSIS requires →
  - A membrane
  - Proton pump
  - Proton gradient
  - ATP synthase

* Alongwith NADPH, ATP → used immediately in → Biosynthetic phase → takes place in → stroma

responsible for →
- fixing CO_2
&
- synthesis of sugars

* Order of e^- acceptors → PS II → Plastoquinone → Cytochrome B_6F → Plastocyanin → PS I → Fd → FNR

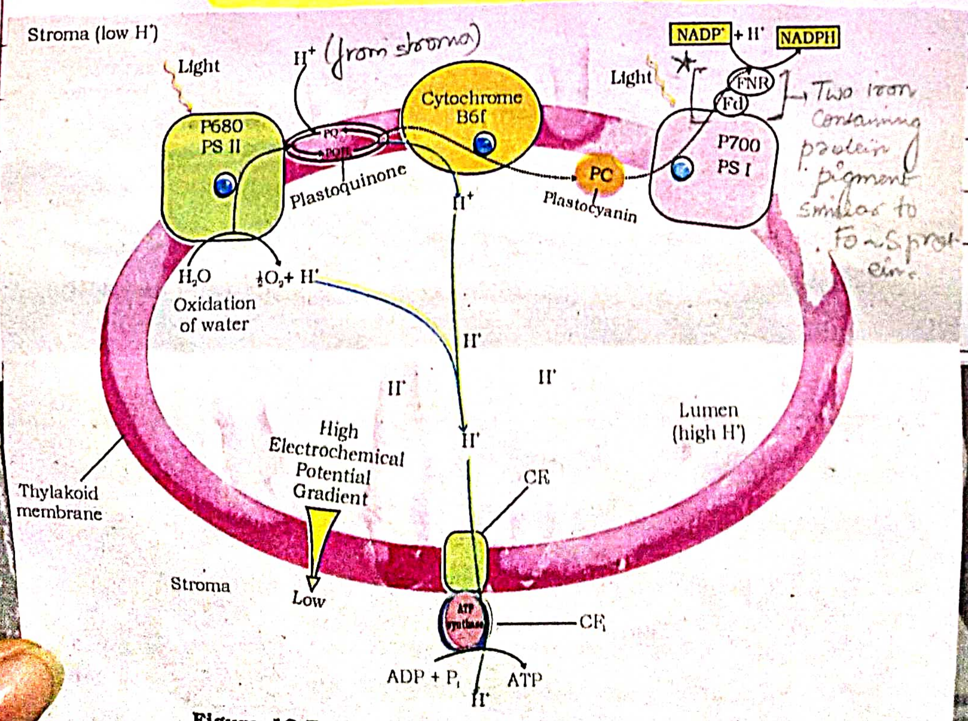


Figure 13.7 ATP synthesis through chemiosmosis

Energy $\xrightarrow{\text{is used to}}$ pump H^+ across a membrane

$\xleftarrow{\text{to create a}}$ gradient / high conc. of H^+

$\xrightarrow{\text{within}}$ Thylakoid lumen

ATP Synthase $\xrightarrow{\text{has a}}$ channel

$\xleftarrow{\text{which allows}}$ diffusion of H^+

$\xrightarrow{\text{back}}$ across the membrane

$\xleftarrow{\text{this releases}}$ Enough energy $\xrightarrow{\text{to activate}}$ ATP synth-ase enzym

catalyze form of ATP

Where are ATP & NADPH used?

* Products of Light rkn – (1) ATP (2) NADPH (3) O_2

* O_2 → diffuses out of the chloroplast
* ATP, NADPH $\xrightarrow{\text{used to drive}}$ processes leading to → synthesis food $\xrightarrow[\text{accurately}]{\text{more}}$ $\boxed{\text{Sugars}}$

BIOSYNTHETIC PHASE → **DARK RKN**

→ does not directly depend on the presence of light
→ BUT dependant on – products of the light rkn.
(ATP   NADPH) besides → CO_2, → H_2O

* If light becomes unavailable → Biosynthetic phase continues for some time → then stop
* When light made available again → Biosynthetic phase starts again

* After World War II, several efforts to put radioisotopes to beneficial use.

$\boxed{\text{Melvin Calvin}}$ $\xrightarrow{\text{used}}$ Radioactive ^{14}C
→ in → Alga photosynthesis
$\xrightarrow{\text{studies led to the discovery}}$ 1st CO_2 fix. product – 3-C organic acid (3-PGA)

Experiments conducted over → Wide range of plants → scientist found → in some plants → 1st fixation product → organic acid ← BUT 4-C → OAA

Since then, (2 types) of CO_2 assimilation in photosynthesis

C3 cycle	C4 cycle
1st CO_2 fix. product – PGA (3C)	1st CO_2 fix. product – OAA (4C)

* In C_3 cycle → Primary acceptor of CO_2 — (5C) RuBP
(Ribulose bisphosphate)

CALVIN CYCLE

Date / /
Page

- Calvin & his co-workers $\xrightarrow{\text{found a}}$ whole, cyclic pathway RuBP was generated.

* Calvin cycle $\xrightarrow{\text{occurs in}}$ ALL PHOTOSYNTHETIC PLANTS.

→ 3 STAGES →

* CARBOXYLATION
- → fixation of CO_2 $\xrightarrow{\text{into a}}$ ① stable ② organic intermediate
- → MOST CRUCIAL STEP of C_3 cycle
- → CO_2 utilised $\xrightarrow{\text{for carbonylation of}}$ RuBP (RIBULOSE-1,5-BISPHOSPHATE)
- → This reaction is catalyzed by – RuBP carbonylase (RuBisCo)
- → Results in formation of – 2 × 3-PGA

* RuBP carboxylase has oxygenase activity too $\xrightarrow[\text{if would be correct}]{\text{so}}$ Call it RuBisCo ↓ Ribulose Bisphosphate carboxylase oxygenase.

* REDUCTION

$1 CO_2$ $\xrightarrow[\text{② 2NADPH → for reduction}]{\text{utilises: ① 2ATP → for phosphorylation}}$ Triose phosphate (PGAL) → Sucrose, Starch

* 6 turns of cycle required $\xrightarrow{\text{for formation of}}$ 1 glucose

* REGENERATION $\xrightarrow{\text{of}}$ RuBP (CO_2 acceptor molecule)
- → CRUCIAL if cycle is to continue uninterrupted
- → Requires – 1 × ATP (for phosphorylation) $\xrightarrow{\text{to form}}$ RuBP

For every $1 \times CO_2$ molecule $\xrightarrow[\text{require}]{\text{Calvin cycle}}$ 3 × ATP, 2 × NADPH

It is possible to meet this difference in number of ATP / NADPH used in dark rxn → Cyclic phosphorylation takes place

In	Out
$6 \times CO_2$	1 glucose
$18 \times ATP$	$18 \times ADP$
12 NADPH	12 NADP

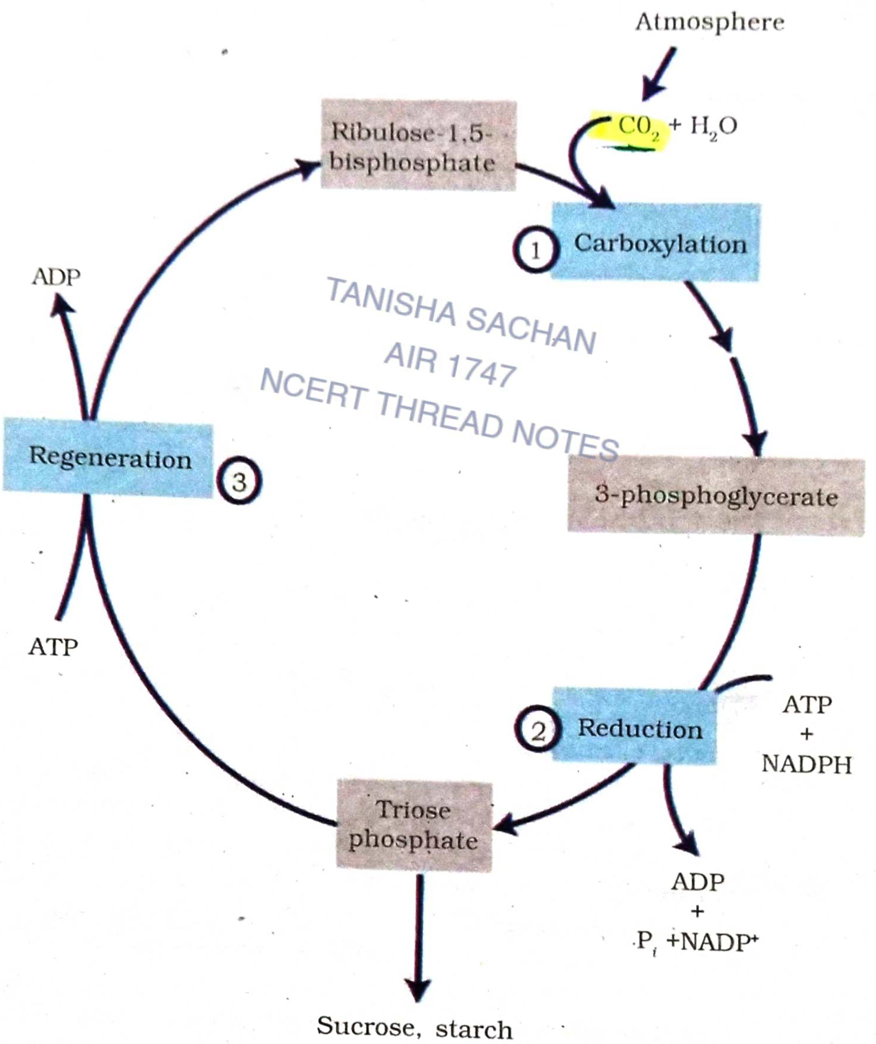


Figure 13.8 The Calvin cycle proceeds in three stages : (1) carboxylation, during which CO_2 combines with ribulose-1,5-bisphosphate; (2) reduction, during which carbohydrate is formed at the expense of the photochemically made ATP and NADPH; and (3) regeneration during which the CO_2 acceptor ribulose-1,5-bisphosphate is formed again so that the cycle continues

C_4 PATHWAY

Date ___/___/___
Page ___

→ Done by — Plants $\xrightarrow[\text{to}]{\text{adapted}}$ ① Dry ② Tropic region → MAIZE → SORGHUM.

* First CO_2 fixation product — C_4 oxaloacetic acid

→ they use → C_3 / Calvin cycle [as their Main biosynthetic pathway]

* C_4 plants are special
  - They have special type of leaf anatomy
  - They tolerate high temp.
  - They show response to high light intensities
  - They lack photorespir-ation
  - Greater productivity of Biomass

* In $\boxed{C_4 \text{ plants}}$, there are LARGE cells around the VASCULAR BUNDLE → Bundle Sheath cells (BSC)

→ Leaves of such anatomy → 'Kranz' anatomy
↳ means "wreath"
↳ reflection of arrangement of cells.

* BSC $\xrightarrow{\text{may}}$ form several layers around V.B

characterised by
  - Large no. of chloroplast
  - Thick impervious walls to gas. exchange
  - No intercellular spaces

* Pathway has been named "HATCH AND SLACK PATHWAY" — cyclic process.

* Primary CO_2 acceptor — PEP (Phosphoenol pyruvate) - 3C
  | present in
  Mesophyll cells. → RuBisCo lack
  ↓
  C_4 acid — OAA, formed here
  Oxaloacetic acid
  | changed into
  ↓
  Malic or Aspartic acid (C_4 acid) in mesophyll only

* Enzyme responsible for this CO_2 fixation
↓
PEP carbonylase / PEPcase

transported to → BSC → where C_4 acids broken down to release CO_2 + 3C-molecule

3C comp $\xrightarrow{\text{transported back to}}$ mesophyll cells $\xrightarrow{\text{where it becomes}}$ PEP completing cy

CO_2 $\xrightarrow{\text{released in}}$ BSC $\xrightarrow{\text{enters}}$ C_3 cycle → A pathway common to all plants.

BSC → Rich in RuBisCo – Ribulose Bisphosphate Carboxylase Oxygenase

BSC → lacks PEPcase

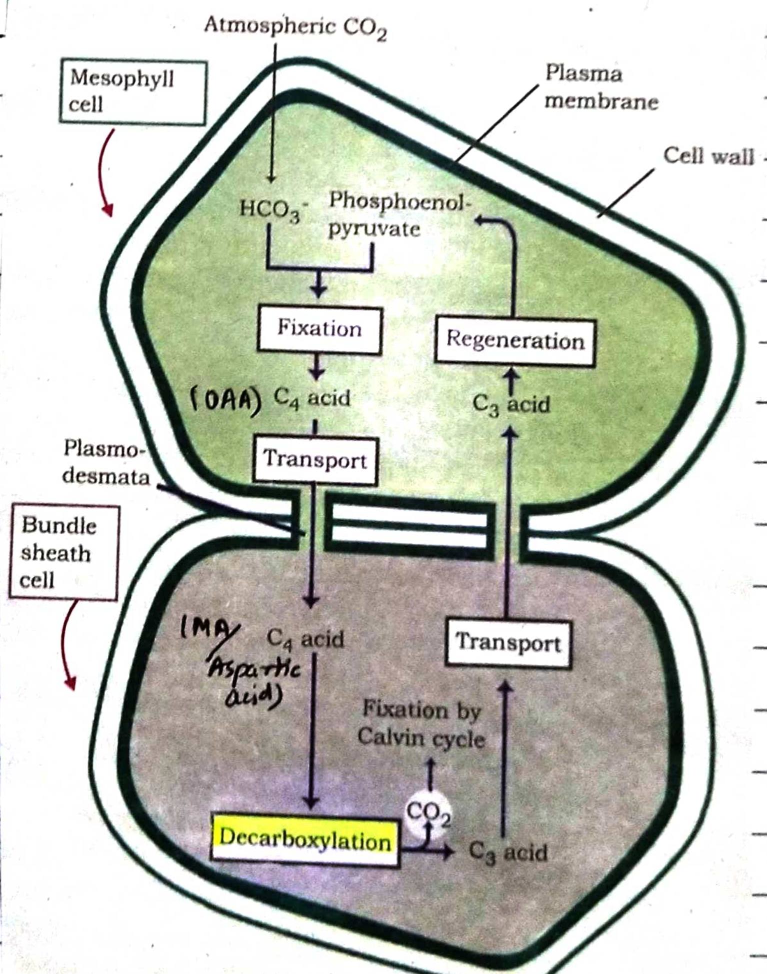
* Basic pathway – C_3 cycle that results in form. of sugars. $\xrightarrow{\text{common to}}$ C_3 plants, C_4 plants

C_3 cycle occurs in	In C_3 plants mesophyll cells	In C_4 plant – BSC

$\boxed{\text{Some important points}}$

1) C_4 plants have → $\boxed{\text{DIMORPHIC CHLOROPLAST}}$

- Granal → In mesophyll cells → Light rkn
- Agranal → In BSC → C_3 cycle



2) CO_2 from atmosphere is accepted as HCO_3^- (diagram)

(carbonic anhydrase)

BALANCE SHEET

ATP used	used $NADPH_2$
$C_3 \rightarrow 18$ ATP	$C_3 \rightarrow 12$ $NADPH_2$
$C_4 \rightarrow 6 \times 2$ ATP	$C_4 \rightarrow 0$
30 ATP	12 $NADPH_2$

For ;
1 glucose out
6 CO_2 in

Characteristics	C_3 Plants	C_4 Plants	Choose from
Cell type in which the Calvin cycle takes place	Meso	BSC	Mesophyll/Bundle sheath/both
Cell type in which the initial carboxylation reaction occurs	Meso	Meso	Mesophyll/Bundle sheath /both
How many cell types does the leaf have that fix CO_2.	1 Meso	2 Meso, BSC	Two: Bundle sheath and mesophyll One: Mesophyll Three: Bundle sheath, palisade, spongy mesophyll
Which is the primary CO_2 acceptor	RuBP	PEP	RuBP/PEP/PGA
Number of carbons in the primary CO_2 acceptor	5	3	5 / 4 / 3
Which is the primary CO_2 fixation product	PGA	OAA	PGA/OAA/RuBP/PEP
No. of carbons in the primary CO_2 fixation product	3C	4C	3 / 4 / 5
Does the plant have RuBisCO?	Yes	Yes	Yes/No/Not always
Does the plant have PEP Case?	No	Yes	Yes/No/Not always
Which cells in the plant have Rubisco?	Meso	BSC	Mesophyll/Bundle sheath/none
CO_2 fixation rate under high light conditions	Low	High	Low/ high/ medium
Whether photorespiration is present at low light intensities	Negligible	Negligible	High/negligible/sometimes
Whether photorespiration is present at high light intensities	High	Negligible	High/negligible/sometimes
Whether photorespiration would be present at low CO_2 concentrations	High	Negligible	High/negligible/sometimes
Whether photorespiration would be present at high CO_2 concentrations	Negligible	Negligible	High/negligible/sometimes
Temperature optimum	20-25°C	30-40°C	30-40 C/20-25C/above 40 C
Examples	Wheat Rice Oat Bamboo Potato	Sugarcane Maize Sorghum Amaranthus Paniceum Pearl millet	Cut vertical sections of leaves of different plants and observe under the microscope for Kranz anatomy and list them in the appropriate columns.

PHOTORESPIRATION

In - Wheat, Rice, Barley

RuBisCo → Most abundant Enzyme in the world.

- → Characterised by - active site $\xrightarrow{\text{for both}}$ CO_2 / O_2
- → Has much greater affinity $\xrightarrow{\text{for}}$ CO_2

⊙ Binding of O_2 & CO_2 with RuBisco $\xrightarrow{\text{is}}$ Competitive

* Relative conc. of O_2 & CO_2 $\xrightarrow{\text{determines}}$ Binding of them with RuBisco

* In C_3 plants

Some O_2 $\xrightarrow{\text{does bind to}}$ RuBisCo $\xrightarrow{\text{hence}}$ CO_2 fixation is ↓↓

* In Photorespiration ;

RuBP (5C) $\xrightarrow{\text{converts to}}$ 1 mol phosphoglycerate (PGA) (3C) + 1 mol. phosphoglycolate (2C)

* There is no synthesis of → Sugars, → ATP

* Rather there is utilisation of → ATP to release → CO_2

* In this pathway, no synthesis of → ATP, → NADPH

* Biological function of photorespiration → Not known yet

CPM

* (In C_4 plants) → photorespiration does not occur

BECAUSE → They have a mechanism $\xrightarrow{\text{that}}$ ↑↑ CO_2 conc → at enzyme site

enzyme site $\xrightarrow{\text{takes place when}}$ C_4 acid (from mesophyll) $\xrightarrow{\text{broken down to release}}$ CO_2 (in BSC)

This results in ↑↑ intracellular conc of CO_2 $\xrightarrow{\text{in turn}}$ this ensures that RuBisCo

RuBisCo $\xrightarrow{\text{functions as}}$ Carboxylase, minimising oxygenase activity

* Hence, C_4 plants have → Better yield & productivity
→ Tolerance to higher temp

FACTORS AFFECTING PHOTOSYNTHESIS

Date 1 | 10

* Rate of photosynthesis $\xrightarrow[\text{in determining}]{\text{is very important}}$ yield of plants (including crop plants)

* Photosynthesis $\xrightarrow[\text{influence of}]{\text{is under the}}$ several factors both → internal (plant) / → external

Internal factors

* These factors are dependent on → genetic disposition / → growth of the plants

* It includes:
  - Size
  - Number
  - Age
  - Orientation

  of → • Leaves • Mesophyll cells • Chloroplasts

  - Internal CO_2 conc.
  - Amount of chlorophyll

External factors

* It includes:
  - Availibility of → sunlight, temp, CO_2 conc., water

* As plant photosynthesise → All these factors simultaneously affect its rate

Rate will be determined by factors availible at sub-optimal levels. $\xleftarrow{\text{hence at any point}}$ [One factor is ① major cause or ② Limiting rate ← usually

* When several factors affect any biochemical process → Blackmann's law of Limiting factor (1905) comes into effect.

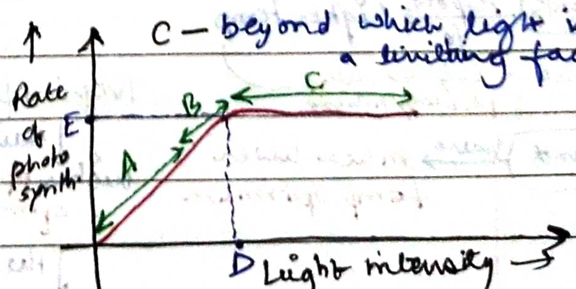
[When several factors affect a chemical process, then its rate will be determined by the factor which is nearest to its minimal value; is the factor which directly affects the process if quantity is changed!] ← THIS STATES

① LIGHT

D — light intensity beyond which light doesn't affect photosynthesis.

C — beyond which light is not a limiting factor

(*) Linear relationship
incident light ∝ CO_2 fixation rates (at low light intensities)



⊙ At higher intensities, gradually rates does not show further ↑ as other factor become limiting

(*) Light saturation $\xrightarrow[\text{at}]{\text{occurs}}$ 10% of full sunlight

Limiting factor in region A — CO_2, H_2O, Light
Light is limiting in region — A & 50% of B

* Hence, except for → plants in shade / dense forests
Light is rarely a limiting factor in nature.

Increase in incident light beyond a point → cause → Breakdown of chlorophyll. & → decrease in photosynthesis

CO_2 Concentration

CO_2 — major limiting factor for photosynthesis

its concentration in atmosphere → very low b/w → (0.03 – 0.04)%

increase in conc. upto → 0.05% → can cause → ↑ increase in CO_2 fixation rates

can be damaging over longer periods ← beyond 0.05% CO_2

* C_3 & C_4 plants respond differently to CO_2 conc.

At low light intensities — Neither responds to CO_2 conc.

At high light intensities — Both C_3 & C_4 show an increase in rates of photosynth.

* Saturation for
  - C_3 plants → Beyond 450 μlL^{-1}
  - C_4 plants → ~~Beyond~~ At/about 360 μlL^{-1}

* Thus, current availability of CO_2 levels is limiting to C_3 plants
* Fact that → C_3 plants respond to higher CO_2 conc. by showing ↑↑ increased rates of photosynthesis leading to higher productivity
  has been used for some Green house crops → Tomato, Bell pepper → They are allowed to grow in CO_2 enriched atmosphere to higher yeilds

TEMP

- Dark rkns → Enzymatic, hence Temp. controlled
- Light rkns also → temp. sensitive but affected by a lesser extent

C_4 plants → respond to higher temp → show higher rate of photosynthesis

C_3 plants → have much lower temp optimum

Temp. optimum for different plants → depends on → habitat they are adapted to

Tropical plants → have higher temp optimum → than the temperate climates plants.

WATER

* One of the reactants in light rkn.
* Its effect is more on plants rather than directly photosynthesis

* Water stress → causes → Closure of stomata → hence ↓↓ CO_2 availability

* Water stress makes leaves wilt → thus ↓↓ surface area → Metabolic activity ↓↓

Organelles involved,

① Chloroplast → ② Perioxisome → ③ Mitochondria